than upon the real genetic and morphological relations of the deposit. Hence it is that Dr. Beck places the pyritic deposits of Rio Tinto, Mount Lyell, &c., in quite a different group from those of Sudbury, although most authorities prefer to group them together. Moreover, it is only in very few of the examples cited under this head that the magmatic origin of the deposit can be said to be in any degree probable.

The class of the stratified ore deposits is better defined, although it would have been preferable to have either excluded altogether deposits that consist of ores disseminated through an otherwise barren bed, or else to have included all forms of this mode of occurrence; the attempt to class impregnations amongst the epigenetic deposits, and to include in the present class only such disseminations as were formed contemporaneously with the bed in which they occur, is necessarily unsatisfactory, for there are very few instances in which the true mode of origin of such deposit has been proved beyond the possibility of dissent. Another source of weakness in this classification is the inclusion here of typically lenticular deposits, whenever the lens lies parallel to the stratification. Here again a relatively accidental character has been emphasised whilst the real geological relations of the deposit have been lost sight of.

Dr. Beck is perhaps at his best in his classification of veins, although the method here adopted is purely empirical. Such important geological relations as those of the vein to the country rock are utterly disregarded, contact veins are not distinguished from true fissure veins, &c., whilst the classification relies entirely upon the mineralogical character of the vein filling. This is the old Freiberg classification, revised and extended, and though it is less satisfactory when applied to the world as a whole than it was when restricted to the Freiberg district, it is nevertheless interesting, and, to a certain degree, even useful. By far the worst portion, and the only one that is wholly unsatisfactory, is the attempt to classify the gold-bearing veins, the distinctions here drawn being far too artificial, and the lines of demarcation too imaginary.

It may be noted, by the way, that the well-known Sheba deposit is here classed as a vein, whilst the bulk of what is known about it tends to show that it is certainly a bed. It is also doubtful whether the majority of the cinnabar deposits are really veins, as they are here designated.

In pointing out that many and grave faults can be found with Dr. Beck's classification of ore deposits, nothing more is intended to be conveyed than that Dr. Beck has not succeeded where every one else has failed. It may be doubted whether any one has yet evolved a classification of ore deposits that satisfied anybody—even its author; the inherent difficulties of the subject are so great and so manifold that a satisfactory solution of the problem may, in the present state of the science, fairly be declared to be impossible. Classification apart, Dr. Beck's work forms a contribution of the utmost value to the study of ore deposits; his descriptions are concise and clear, and his illustrations are well selected, especially as regards German, Austrian and Scandinavian deposits. The section on faults is eminently satisfactory, and indeed it would be hard to point to any work in which this complicated portion of the subject has received better treatment. It is difficult to pass judgment on half a book, but it may fairly be said that if the remainder of the work is only equal to the first half, it will constitute one of the best works available on the subject of ore deposits, provided that it is furnished with thoroughly complete indexes, and not with the apology for an index that usually does duty in German works. As the ore deposits described are arranged in accordance with the author's own system of classification, a complete alphabetical subject-index, together with a complete alphabetical index of geographical names, are needed to make Dr. Beck's work the highly useful book of reference that its other merits entitle it to become. H. Louis.

THE THEORY OF "SCREWS."

A Treatise on the Theory of Screws. By Sir Robert Stawell Ball, LL.D., F.R.S. Pp. xix + 544. (Cambridge University Press, 1900.)

SIR ROBERT BALL'S "Theory of Screws" is one of the most notable modern extensions of theoretical dynamics. It is based on Poinsot's discovery that every set of forces, regarded as acting on a rigid body, is reducible to a force along one definite line and a couple round the line; combined with Chasles's discovery that every instantaneous motion of a rigid body is reducible to rotation round one definite line and translation along it—in other words to a screwing motion. The modes of reduction in the two cases are strictly analogous; a force along a line being the analogue of a rotation round the line, and translation in any direction being the analogue of a couple whose axis has this direction.

The theory of screws treats of these two subjects in conjunction. The definite line along which the force acts, or round which the body rotates, is regarded as the *axis* of a *screw*, and the ratio of the couple to the force in the one case, or of the translation to the rotation in the other, is called the *pitch* of the screw. The sign of the pitch indicates whether the screw is right-handed or left-handed, and is not altered by reversing the screw end for end.

It would be convenient to have some general name for anything which follows the laws of combination employed in these reductions. Clifford called it a *motor*. It might well be called a *screw-actor*. The resultant of two screw-actors may be called their *sum*.

When the screw-actor is a set of forces, Sir R. Ball calls it a *wrench*—a name which is not suggestive of a statical concept, but rather of force combined with motion. The name *forcive* seems more appropriate.

When the actor is a screw motion, Sir R. Ball calls it a *twist*, and the name *twist-velocity* is given to a screw-velocity. The twists considered in the theory of screws are, in general, supposed to be so small as to admit of simple superposition, quantities of the second order being negligible.

Five numbers are required for specifying a screw. Two will give the direction of the axis, two the intersection of the axis with a fixed plane, and one the pitch. From another point of view a screw is defined by the five ratios of the six components of a screw-actor.

The theory of screws lends itself with special readiness to the discussion of the movements of a body with a given number of degrees of freedom. A body with one degree of freedom can only move on one definite screw. A body with two degrees of freedom can take two independent screw motions combined in any ratio. This gives an infinite number of resultant screws, all lying in one ruled surface (called a *cylindroid*) and having pitches distributed according to a simple law. All cylindroids have the same shape, and the linear dimensions of a cylindroid are proportional to the difference between the greatest and least pitch that can be found among its screws. A body with n degrees of freedom has n independent screw motions, n being not greater than 6.

Any screw system which specifies the freedom of a body serves equally well for specifying aggregates of screw-actors of the forcive kind. For instance, if any multiple (integral or fractional) of a forcive on a screw A is compounded (additively or subtractively) with a forcive on a screw B, the resulting forcive will be on one of the screws of the cylindroid to which A and B belong.

A body limited to motion on one definite screw can move in either of two opposite directions, and when acted upon by a forcive will move in the direction for which the work done by the forcive is positive. When the forcive-screw is so related to the motion-screw that the work-rate for a small motion is zero, the body will be in equilibrium, the forcive being equilibrated by the reaction of the constraints. The two screws in this case are said to be *reciprocal.* The condition of reciprocity, when expressed in terms of the rectangular components X Y Z of force, $u\ v\ w$ of translation, L M N of couple, and $p\ q\ r$ of rotation, is

$$Xu + Yv + Zw + Lp + Mq + Nr = 0\,;$$

and this will not be altered by interchanging the force X with the rotation p, the couple L with the translation u, and so on. Hence it is immaterial which of the two screws we assign to the forcive and which to the motion.

One degree of constraint subjects the 6 components, $u\ v\ w\ p\ q\ r$, of an instantaneous motion to one linear relation. It can accordingly be expressed by assigning proper values to the coefficients X Y Z L M N in the above equation of condition. One degree of constraint, therefore, limits the motion of a body to those screws which are reciprocal to one definite screw. Hence it can be deduced that two degrees of constraint limit the motion to screws reciprocal to all the screws of one definite cylindroid.

The system of screws on which a body can move which has n degrees of freedom or $6-n$ degrees of constraint being called an *n system*, it can be shown that every n system is reciprocal to a definite $6-n$ system. Each of these two systems is sufficient to define the other.

In a 5 system the axes of the screws include every line in space, each fitted with its proper pitch, and at every point there are a whole plane of screws of any assigned pitch.

Three or more screws are said to be independent when it is not possible to take screw-actors upon them whose sum is zero. Seven screws cannot be independent. If any 6 independent screws are taken, they will suffice for the specification of any 7th screw by 6 numerical coefficients, called *screw-coordinates*, an actor on the 7th screw being always a sum of multiples (generally fractional) of actors on the 6 screws of reference. It is possible, and usually preferable, to select screws of reference such that each is reciprocal to all the rest.

If a body is only free to move on a single screw, a forcive applied to it can be resolved into two forcives, one of which is reciprocal to the screw in question. This component can be ignored, as it does not influence the motion, which will accordingly be the same as if the other screw acted alone. If a body has n degrees of freedom, a forcive applied to it can be resolved into 6 mutually reciprocal forcives of which $6-n$ are without influence on the motion, and the other n may be regarded as acting alone.

The initial motion of a body produced by an impulsive forcive is, in general, on a different screw from the forcive; but in certain cases they are on the same screw. (This means that they have the same axis, and the work in translation is equal to the work in rotation). The screw, common to both, is then called a *principal screw of inertia.* There are, in general, 6 such screws for a perfectly free body, and n for a body with n degrees of freedom.

Again, for a body in stable equilibrium under forces which have a potential, there are certain screws (generally equal in number to the degrees of freedom) such that if the body be slightly displaced along one of these screws, and then left to itself either at rest or with a velocity on the same screw, it will oscillate on this screw. The screws thus defined are called *harmonic*, and are the proper screws to select for specifying small oscillations.

Besides physical deductions, of which the foregoing are specimens, the treatise contains numerous geometrical investigations, and an extension of the theory to non-Euclidian space.

At the end of the volume an interesting summary is given of the literature of the subject. It appears that Hamilton, in one of his papers on systems of rays, and Plücker, in his *New Geometry of Space*, anticipated Sir R. Ball's discovery of the cylindroid so far as regards its geometrical form without reference to pitch; and several theorems respecting systems of lines had been discovered which are particular cases of the general theory of screws.

An amusing and instructive "Dynamical Parable," which formed Sir R. Ball's Presidential Address to Section A at the 1887 meeting of the British Association, is given as an Appendix.

I wish to point out an erroneous statement with regard to finite displacements which occurs in all our works of highest authority on the motion of a rigid body. It is to be found in *Routh*, in *Thomson and Tait*, in *Williamson and Tarleton*, and in the introduction to Sir R. Ball's *Treatise.* The erroneous statement, in its plainest shape, is "The same displacement cannot be constructed on two different screws."

To see that this is wrong, consider the effect of giving a nut 9¼ turns on an ordinary iron screw. The same final position could obviously be attained by employing a screw of longer pitch and taking fewer turns, say 8¼ or 1¼ or ¼, and could also be attained by taking ¾ or 1¾ or 8¾ turns on a left-handed screw. The correct statement is that the axis and translation are unique, but that the rotation has any one of an indefinite number of values differing each from the next by 2π, some of them being positive (right-handed) and some negative (left-handed). If l is the translation, and p_0 one value of the pitch p, the general value of p is given by

$$\frac{1}{p} = \frac{1}{p_0} \pm \frac{2n\pi}{l}.$$

J. D. EVERETT.

CULTIVATION AND MANUFACTURE OF TOBACCO.

Le Tabac Culture et Industrie. By E. Bouant. Pp. xii + 347. (Encyclopédie Industrielle, Paris: J. B. Baillière et fils, 1901.)

THE object of this work, as stated by the author in the preface, is to describe in popular scientific language the long series of operations necessary to transform a tiny seed into a good cigar or a pinch of scented snuff.

In a short introduction the author gives a *résumé* of the best ascertained facts concerning the origin of tobacco, its introduction into Europe, the prohibitions intended to hinder its use, and the change of tactics which have resulted in making the smoker contribute his quota to the public revenue.

Of the three parts into which the book is divided, the first two deal with the cultivation and manufacture of tobacco, and in the third part the economic, fiscal and hygienic aspects of tobacco are discussed.

In France the State controls the cultivation, and has the monopoly of the manufacture of tobacco; the author restricts his treatment of the subject almost entirely to a description of the methods of culture and manufacture followed in France.

Part i. commences with the botany of the principal species of Nicotiana and with a short account of the chemistry of tobacco. According to the analyses given on p. 24, tobacco ash contains a large proportion of salts of sodium (16 per cent. in the ash from the leaves of Havana tobacco). This is at variance with the general experience, for it is a remarkable and well-established fact that tobacco contains very little soda in any form.

The subject of culture is dealt with very fully, and a large amount of information is given concerning the choice of the most favourable soils and manures, the rotation of crops, sowing and transplanting, the various field operations during growth and ripening, and the final operations of harvesting, curing and packing.

In view of the experimental cultivation of tobacco which has been carried on in Ireland during the past season, it is interesting to note that the experience gained in France shows that Europe will never be able to dispense with American tobacco, as, with rare exceptions, European varieties are inferior in aroma and combustibility to those of American origin.

The manufacturing methods described in the second part are those employed in the great State tobacco factories of France. The methods of manufacturing cut and roll tobacco and snuff differ materially from those followed by British manufacturers, the result, no doubt, of the different fiscal regulations in the respective countries. The methods employed for making cigars and cigarettes, on the whole, are the same in both countries.

The book is well illustrated and, with the exception of a few photographic reproductions which leave much room for improvement, the illustrative figures are good and clear; typographical errors are not numerous. Altogether it is a very readable work, and, in addition to being interesting to the general reader, it should be of some service to those engaged in the cultivation and manufacture of "our holy herb Nicotian." J. W.

OUR BOOK SHELF.

Briefwechsel zwischen Franz Unger und Stephan Endlicher. Herausgegeben und Erlaütert von G. Haberlandt. Pp. v. + 184. (Berlin: Borntraeger, 1899.)

AFTER the death of Unger's surviving son and daughter, a large portion of his correspondence was presented to the Botanical Institute of the University of Graz. From amongst these remains Prof. Haberlandt gives to the world the almost complete series of letters which passed between Unger and Endlicher from 1829 to 1847. There are 139 letters in all, of which about two-thirds are by Unger. Though the correspondence is, in large part, concerned with their own botanical labours, all the more important contemporary contributions to Botany are discussed between the friends. At the date of the opening of this correspondence, neither of the writers held an independent botanical post. Unger, who had deserted the law and qualified in medicine, in 1830 became a medical officer at Kitzbühel, in the northern Tyrol. Here, during his five years' sojourn, he collected the material for and wrote his now classic "Einfluss des Bodens auf die Vertheilung der Gewächse." This was the first attempt at a physiological flora, and Unger was justly proud of his achievement. This and other work paved the way to the professorship at Graz, to which he was appointed in the autumn of 1835, and which he held till Endlicher's death. Endlicher, the author of the well-known "Genera Plantarum," was made keeper of the botanical department in the Hof Museum, at Vienna, within a few months of Unger's appointment to Graz. Many common undertakings were mooted between the friends, and the most notable of those which reached accomplishment was their joint "Lehrbuch der allgemeinen Botanik," published in 1843. Its inception and progress are very fully set forth in the letters, and this portion of the correspondence will be read with interest as effectively contrasting the character and temperament of these two men. That Schleiden should have chosen the same time to bring out his remarkable "Grundzüge der wissenschaftlichen Botanik" was an event which could not fail to impress the joint authors. Unger, with characteristic outspokenness, writes:—"What do I think about Schleiden? He is an excellent fellow, though I don't agree with him entirely. We have wanted a man like this for a long time. It is by him—not by us—that a new epoch is created in our science." Another part of the correspondence, that relating to Unger's discovery of the ciliated zoospores of *Vaucheria*, is also full of interest. The headstrong and enthusiastic Unger insists on announcing his discovery in the form of a series of popular letters under the title "The Plant at the Moment of becoming an Animal," with an absurd quotation from Oken (the nature-philosopher) as motto. This intention draws from Endlicher one of the best letters in the book (No. 100); but it is quite lost upon Unger.

The correspondence is preceded by an able appreciation of the two botanists by Prof. Haberlandt, the present occupant of Unger's chair at Graz; whilst, by way of conclusion, there is printed a series of documents which tends to show that Endlicher died a natural death and did not commit suicide, as has been generally believed.